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Performance Evaluation of Subsurface Drainage System at Appikalta Drainage Pilot Area in Krishna Western Delta Using 'Drainmod'

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ABSTRACT

Irrigation induced problems of water logging and salinity are noticed in many canal commands in India. Pilot studies conducted in some of these command areas demonstrated the potential of subsurface drainage for the control of salinity and water logging and the improvement of agricultural productivity.. In this study, DRAINMOD model was used to evaluate the performance of subsurface drainage system near Appikatla in Krishna Western Delta. Data collected from a subsurface drained experimental field located geographically at about 15^{0} 28' N latitude and 80^{0} 28' E longitude near Appikatla village in the Krishna Western Delta in Andhra Pradesh. The subsurface drainage system consists of two sub-fields with drains installed at two different spacing's of 30 and 60 m. The model was calibrated by using observed data from the pilot area (7.5 ha) considering an equivalent drain spacing of 50 m during the period from 2004 to 2006 and validated using the observed data from 2007 to 2009. The model predicted variables like drain flow, soil salinity and relative yields of paddy crop were in good agreement with observed data as indicated by good statistical model performance measures (Nash-Sutcliffe model efficiency) EF of 0.57, 0.72 and 0.30 and Coefficient of correlation(R) of 0.88, 0.90 and 1.00 during calibration period and EF of 0.90, 0.64 and -0.42 and R of 0.99, 1.00 and 0.99 during the validation period.

Key words : Calibration, Drain flow, Drainmod, Relative yields, Soil salinity, Validation

The purpose of this article is to evaluate the performance of subsurface drainage system at a pilot area near Appikatla village in Krishna Western Delta using the water management simulation model, DRAINMOD. The model can be used to simulate the performance of a water management system design over a long period of climatological record. By evaluating several designs, the alternative system which satisfies the design objectives at the least cost can be identified. The model has been used by researchers all over the World over the last three decades (Skaggs 1980 and Fouss *et al*. 1987). In India, the model was used by Gupta *et al. 1993.* To compare the predicted mid-span water table heights with the measured ones in four subsurface – drained test plots in Kota, under RAJAD project and found that the average absolute deviations ranged from 14 to 24 cm for the four test plots.

The corresponding standard errors of estimate ranged from 15 to 30 cm. and it was concluded that DRAINMOD could be used to design or evaluate subsurface drainage systems under the semi-arid climatic conditions.

MATERIAL AND METHODS

Model description

The DRAINMOD model is based on the water balance for a thin section of soil of unit surface area which extends from the impermeable layer to the surface and is located midway between adjacent drains (Skaggs. 1978). The water balance for a time increment **Δt** may be expressed as,

$$\Delta V = D + ET + DS - F \quad (1)$$

Where **ΔV** is the change in the volume (cm), **D** is lateral drainage (cm) from the section, **ET** is evapotranspiration (cm), **DS** is deep seepage (cm), and F is infiltration (cm) entering the section during time interval **Δt.**

The amount of runoff and storage on the surface is computed from a water balance at the soil surface for each time increment as,

$$P = F + \Delta S + RO \quad (2)$$

Where **P** is the precipitation (cm), **F** is infiltration (cm), **ΔS** is the change in volume of water stored on the surface (cm), and **RO** is runoff (cm) during time interval **Δt.**

Table 1. Drainage system parameters of Appikatla pilot area

S.No.	Design parameter	Specification
1	Drain spacing	30 m & 60 m
2	Drain depth	0.8 m – 1.1 m
3	Size of drain pipe	Diameter 10 cm
4	Size of collector pipe	15 cm
5	Hydraulic conductivity of soil	0.265 m/d
6	Depth to impervious layer from the surface	4.8 m
7	Drainage coefficient	2 mm/d

Table 2.Soil physical characteristics of the study area

Soil depth	Soil properties						
	Texture (%)			Bulk density (gm/cc)	Moisture content (Θ)		Ksat (cm/hr)
	Sand	Silt	Clay		Θ sat(cc/cc)	Θ pwp(cc/cc)	
L-I (0-50 cm)	30.000	35.300	34.700	1.480	0.510	0.200	1.290
L-II (50 - 100 cm)	30.200	35.800	34.000	1.480	0.510	0.200	1.125
L-III(100-150 cm)	31.500	35.800	34.100	1.480	0.500	0.170	5.750

Table 3. Ranges of calibration parameter and selected values.

Parameters	Layer	Range	Selected values
Volumetric soil moisture at 0 cm tension	Layer 1 (0-50cm)	0.510-0.400	0.410
	Layer 2 (50-100cm)	0.510-0.400	0.410
	Layer 3 (100-150cm)	0.480-0.350	0.390
Lateral saturated hydraulic conductivity ($cm\ h^{-1}$)	Layer 1 (0-50cm)	1.000-6.000	5.000
	Layer 2 (50-100cm)	5.000-20.00	18.00
	Layer 3 (100-150cm)	10.00-3000	28.00
Surface micro storage S_m(cm)	1.000 – 5.000	4.000	-
Depth to restricted layer (cm)		140.0 – 390.0	150.0
Drainage co-efficient (cm/day)		0.200-2.000	1.700

Table 4. Statistical performance of DRAINMOD for Drain Flow in pilot area during calibration period.

Parameter	PE range	RMSE	CRM	EF	R
Drain flow	- 4.3	20.9	-0.043	0.57	0.88
Depth to water table	1.0	13.4	0.01	0.78	0.97
Soil salinity	2.01	6.8	0.020	0.72	0.90
Relative yield	3.7	6.5	0.037	0.30	1.00

Table 5. Statistical performance of DRAINMOD for Drain Flow in pilot area during validation period

Parameter	PE range	RMSE	CRM	EF	R
Drain flow	15.0	16.0	0.015	0.90	0.99
Depth to water table	-3.9	23.2	-0.039	0.69	0.88
Soil salinity	10.22	10.3	0.010	0.64	1.00
Relative yield	13.9	40.6	0.013	- 0.42	0.99

Fig.1. Sub-Surface Drainage system with monitoring network at Appikatla, of Krishna Western Delta.

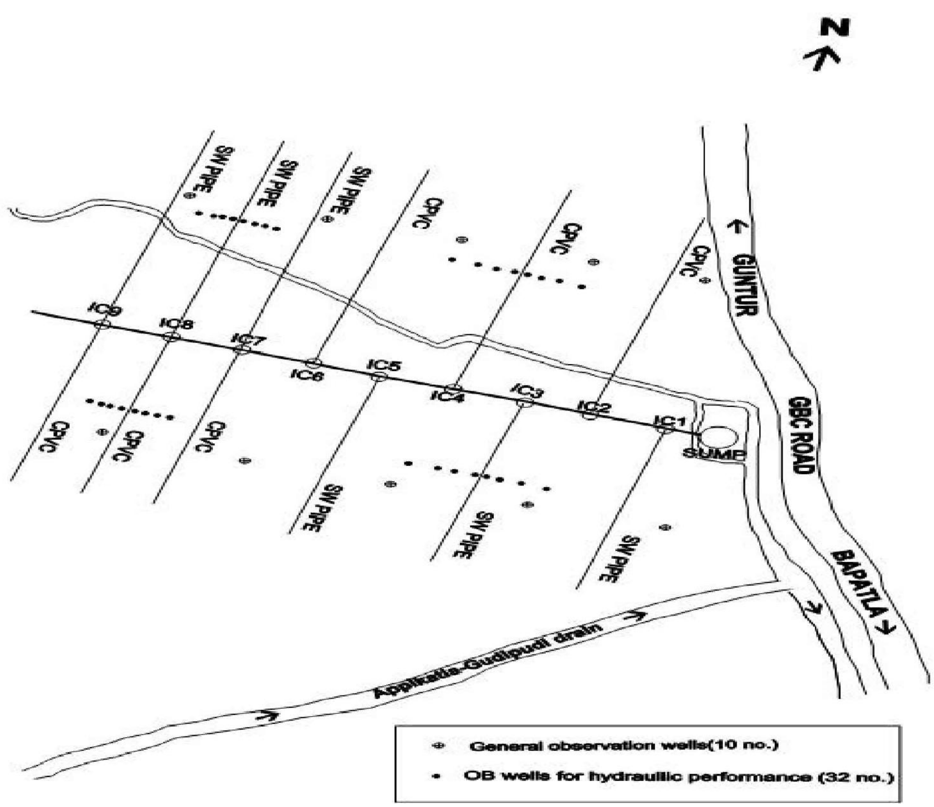


Fig. 2 Comparison of observed and predicted drain flows during calibration and validation periods.

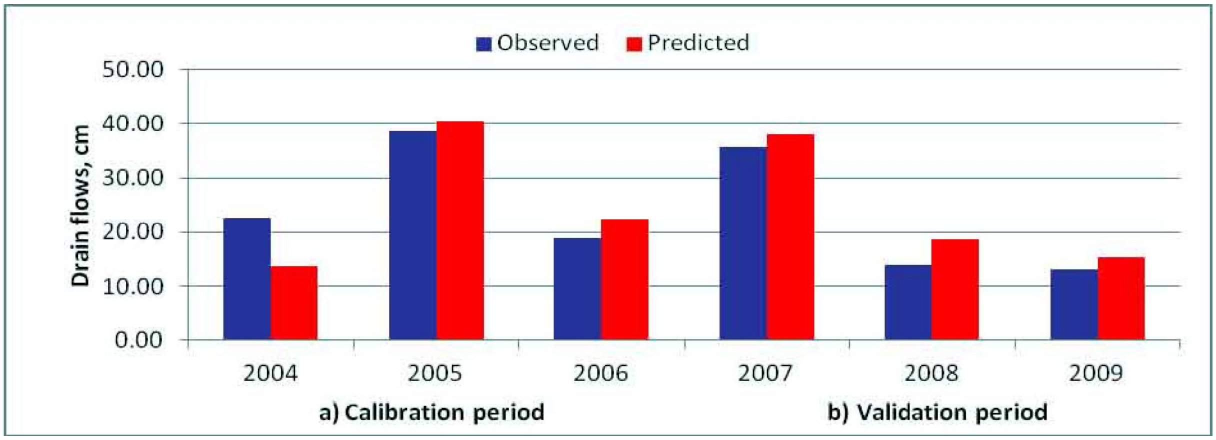


Fig. 3 Comparison of observed and predicted soil salinities during calibration & validation periods.

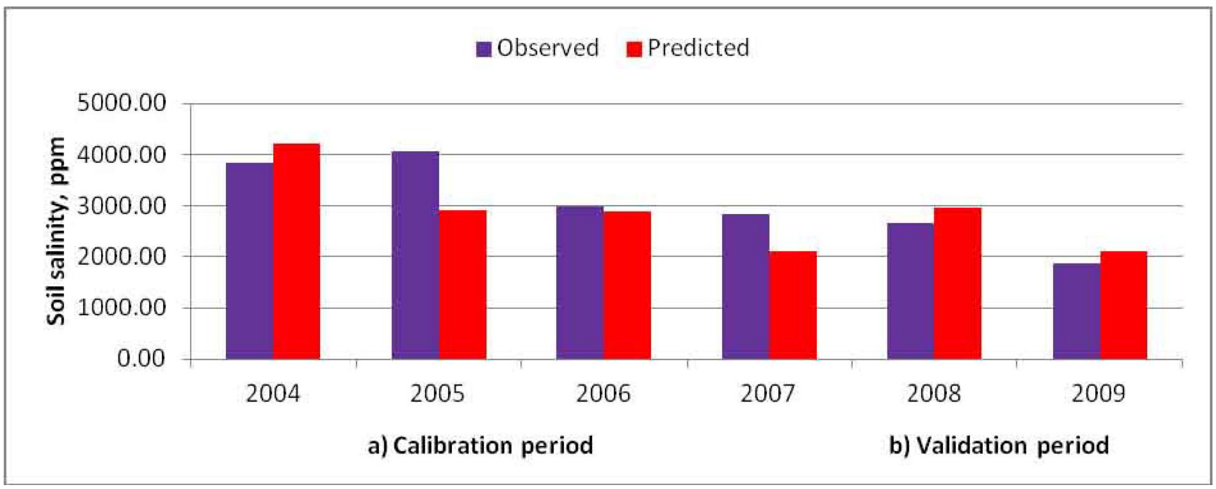
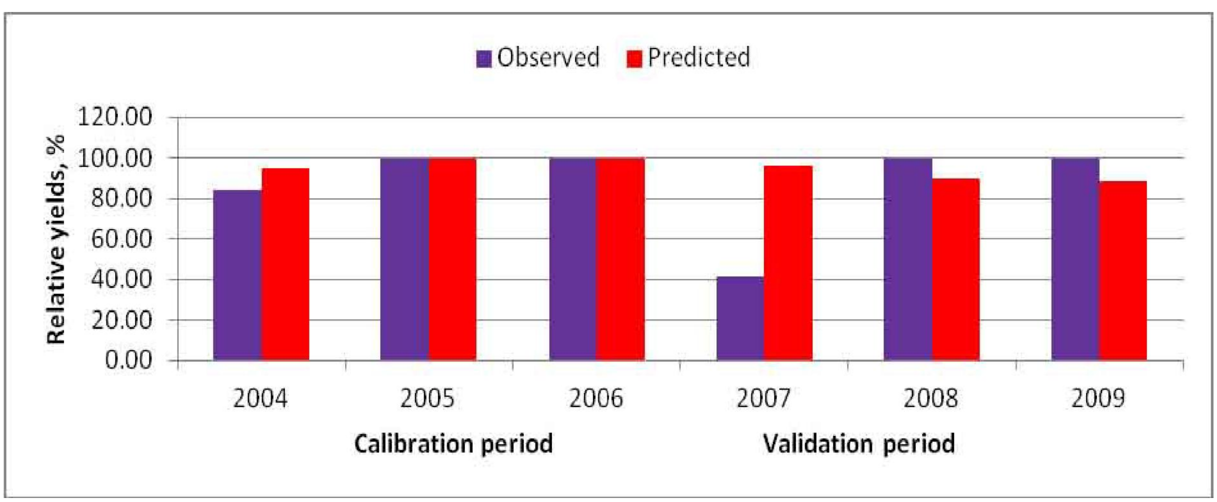


Fig .4 Comparison of observed and predicted relative yields during calibration & validation periods.



Subsurface Drainage and Sub irrigation

Procedures used in DRAINMOD to calculate drainage and sub irrigation rates assume that lateral water movement occurs mainly in the saturated region. The lateral flux is evaluated in terms of the water table elevation midway between the drains and the water level or hydraulic head in the drains. DRAINMOD employs the Hooghoudt steady state equation, as used by Bouwer and van Schilfgaarde (1963). This equation may be written as,

$$q = (8 K d_e m + 4 K m^2) / L^2 \quad (\mathbf{3})$$

where q is the flux (cm/h), d« is the equivalent depth of the impermeable layer below the drain (cm), m is the midpoint water table height above the drain (cm), K is the effective lateral hydraulic conductivity (cm/h), and L is the distance between drains (cm). The model uses a modification of Equation (4) presented by Ernst (1976) to calculate sub irrigation rates in layered soils.

General characteristics of study area

An area of 7.5 ha was selected in Appikatla village located geographically between $15^0 58'$ N Latitude and $80^0 28'$ E Longitude. The project area was bounded by Guntur-Bapatla road in the west and natural main drain in west and east. A main drain passes along the southern boundary of the area.

The water table depth in the project area was within 1.5 m from ground level and it came closer to ground surface during in the *kharif* season. The electrical conductivity (EC) of ground water ranged from a low value of 1.5 dS/m to 21 dS m^{-1} with an average of 8.1 dS/m. It seemed to be the major cause of soil salinization. The ECe of experimental area at a depth of 0-20cm varied from 2.1 to 41.0 dS m^{-1} with an average value of 16.5 dS/m and the p^H ranged from 6.1 to 8.2 with a mean of 7.3.

A pipe drainage system was installed in project area during June 2002 with monitoring network shown in Fig.1. The topography of the pilot area hadn't permitted gravity outflow in to natural drain, which was flowing towards south side of the project area. The design parameters of the system were shown in Table 1. (Ravindra babu *et al.* 2010.

Model inputs

General data

The General Information screen was used to input the title of the simulation, to select output options, to specify period of simulation and to specify the water management options. Information that were included in the title are; location, soil series, date, drain spacing, drain depth, surface storage, and water management mode which includes the following features.

Drainage system parameters

Drainage system parameters were entered through the drainage design window of the model and detailed information about these parameters were discussed in following. A number of input parameters describing the subsurface drainage system were required for each simulation. To correct for convergence near the drains, Moody's equations were used to compute the Hooghoudt equivalent depth to the drainage barrier which will be less than the depth to the actual barrier. The drainage coefficient, DC, (in cm day^{-1}) reflects the hydraulic capacity of the drains, that is, the design flow capacity. This is a function of the drain diameter and the slope of the installed drain.

The maximum surface storage in cm which must be filled before surface runoff occurs and the storage in local depressions such that water is prevented from moving freely to a position over the subsurface drain. The lateral saturated hydraulic conductivity (k) must be obtained for each discrete layer to the effective drainage barrier. Different physical characteristics are shown in Table 2.

Weather information

Potential evapotranspiration, PET, Two options were available for PET file preparation. The 1st was that user could create PET data files or the 2nd was daily maximum and minimum air temperature data files could be used to estimate PET. If the temperature data files were used, then DRAINMOD computed PET using Thornthwaite's equation (1948).

The daily rainfall data as well as the daily maximum and minimum temperature data were collected from the meteorological observation station situated in the Agricultural College Farm. The data used for simulation of model was taken from 1-1-1984 to 31-12-2009. Prepared columnar data file was converted in to model formatted file by utility program of the DRAINMOD.

Soil and crop related data

The soil water characteristic is a basic soil property which is second in importance to only hydraulic conductivity in modeling soil water movement. The soil water characteristics were obtained from the website; *pedosphere.com,* by applying textural analysis of soil layers. The relation between volumes drained versus water table depth, upward flux versus water table depth and Green and Ampt parameters versus water depths were also needed for input information. These relations were obtained from the out put of the soil preparation program in which soil water characteristics were used as input.

The values of Rooting Depths, SEW (Sum of excess soil water), Traffic ability Inputs, Planting Delays, Excess Soil Water Stress, Deficient Soil Water Stress and Salinity Stress were required for testing purpose.

Calibration and validation of the model

This was carried out by comparing the values of some parameters those were observed in the field as well as predicted by the model. In present situation, the model was calibrated by using observed data set during the period from 2004 to 2006. Hydraulic conductivity, volumetric soil moisture at 0 cm head, drainage coefficient and surface storage were considered as calibration parameters with a specific range. Model was run for the number of times by adjusting the values of above considered parameters and fixed the values with minimum errors. Statistical Analysis was carried out with the help of observed and predicted data set. Validation of the model was carried out by using the observed data set during the period from 2007 to 2009. Simultaneously statistical analysis was also carried out to find the errors.

RESULTS AND DISCUSSIONS

The testing and validation of DRAINMOD model was carried out by comparing with variables obtained from drainage system installed during the year 2002 at Appikatla Village of Krishna Western Delta of Andhra Pradesh. Results obtained from calibration, validation, were presented and discussed in this section. Statistical analysis was also carried out to ensure the quality and reliability of model predicted quantities.

Model calibration and validation

The volumetric soil moisture at 0 cm tension, lateral saturated hydraulic conductivities for 3 layers, drainage co-efficient, depth to restricted layer and surface micro storage were calibrated. The range of calibrated and selected values was shown in Table 3. The relation between observed and predicted values of variables like drain flow, soil salinity and relative yields were shown in Fig's.1 (a), 2(a) and 3(a) respectively;

It was clearly observed from Fig's.1 (a), 2(a) and 3(a), the predicted values of variables like drain flow, soil salinity and relative yields were had good agreement with observed values. Statistical analysis also indicated that the performance of model in predicting the values of above variables was good during in calibration period. Detailed statistical analysis of above variables was shown in Table 4.

The calibrated model was validated by comparing the predicted and observed values of above mentioned variables, over the years from 2007 to 2009 for the same project site. An agreement was observed between the predicted and observed values during validation period and relations were shown in Fig's.1 (b), 2(b) and 3(b). The same statistical parameters were used to ensure the quality and reliability of the model as applied during the calibration process. Detailed statistical analysis was shown in Table 5.

Conclusions

1. The correlation coefficient (R) of 0.88, 1.00 and 0.90, model efficiency (EF) of 0.57, 0.30 and 0.80 for drain flow, relative yields and soil salinity, respectively were obtained during the model calibration period.
2. The root mean square error (RMSE) of 20.9, 6.5 and 6.8, percent error (PE) of -4.3, 2.01 and 3.7 for drain flow, relative yields and soil salinity, respectively were obtained during the model calibration period.
3. The correlation coefficient (R) of 0.99, 0.99, and 1.00, model efficiency (EF) of 0.90, -0.42 for drain flow, relative yields and soil salinity, respectively were obtained during the model validation period
4. The root mean square error (RMSE) of 16.0, 40.6 and 10.3, percent error (PE) of 15.0, 13.9 and 10.22 for drain flow, relative yields and soil salinity, respectively were obtained during the model validation period
5. The overall performance of DRAINMOD was satisfactory. The model can be applied for design and evaluation of subsurface drainage systems installed in Krishna Western Delta of Andhra Pradesh

LITERATURE CITED

Anonymous 2002-03 to 2008-09 (7volumes). *Annual progress reports* of AICRP on management of salt affected soils and use of saline water in Agricultural, Bapatla centre, Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India.

Fouss J L, Bengbon R L and Caster C E 1987. Simulating sub- surface drainage in lower Mississippi valley with DRAINMOD. *Trans ASAE* 30: 1679- 1988.

Gupta G P, Prasher S O, Chieng S T and Mathur I N 1993. Application of DRAINMOD under semi- arid conditions. *Agricultural Water Management* 24: 63-80.

Rajasthan Agricultural Drainage Project 1995. Analysis of Subsurface drainage design criteria, RAJAD, Kota, India.

Ravindra Babu P, Raghu Babu M, Prasad P R K, Lakshmi G V and Gupta S K 2010. Subsurface Drainage for Reclamation of Waterlogged Saline Lands in Krishna Westren Delta, *Technical bulletin of AICRP on management of salt affected soils and use of saline water in Agricultura*l, Bapatla centre, Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India.

Skaggs R W 1978. A water management model for shallow water table soils. *Rept.134, North Carolina Water Resource.* Res. Inst. North Carolina State Univ. Raleigh, NC.

Skaggs R W 1980. A Water Management Model for Artificial Drained Soils. *Tech. Bull 267. North Carolina Agric.* Res. Station, North Carolina State University 27650, p. 59.

Thorntwaite C W 1948. An approach toward a rational classification of climate. *Geog. Rev.* 38:55- 94.

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